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NORTH AND SOUTH AMERICAN COPEPODS OF THE GENUS HEMICYCLOPS (CYCLOPOIDA : CLAUSIDIIDAE)

By RICHARD U. GOODING

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NORTH AND SOUTH AMERICAN COPEPODS OF THE GENUS HEMICYCLOPS (CYCLOPOIDA: CLAUSIDIIDAE)

By Richard U. Gooding [1]

Introduction

Species of the genus *Hemicyclops* Boeck have been found on both east and west coasts of the American continents. Those previously described are *thysanotus* Wilson, *callianassae* Wilson, *pugettensis* Light and Hartman, *purpureus* Boeck, *adhaerens* (Williams), *americanus* Wilson and *elongatus* Wilson; *subadhaerens* and *arenicolae* are added in this review. Little is known about their ecology or distribution, but all appear to be intertidal forms or inhabitants of shallow water and some to live in association with other animals. To the latter category belong at least one and possibly both of the new forms described.

This study forms the first part of a revision of the genus *Hemicyclops*. An attempt on the larger task has seemed inappropriate at present for two reasons. First, lack of information on the morphology of larval stages in the Clausidiidae (to which all the genera mentioned in this paragraph belong) prevents an adequate evaluation of Nicholls' suggestion (1944, pp. 49–51) that the genus *Saphirella* T. Scott represents "the young form of *Hemicyclops*." Second, although some trends shown by the species described in this paper suggest that the

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genera *Hersiliodes* Canu (see Bocquet and Stock, 1957, for a discussion of the species currently included in this genus) and *Giardella* Canu can be synonymized with *Hemicyclops*, I have not had a chance to examine representatives of either.

Thus, no definition of the genus is given here. All the species discussed share with the type species (*H. purpureus* Boeck, 1873, coast of Norway) the lack of suckers on any of the appendages, a basic terminal mandibular armature of four articulated processes, the presence in the adult female of well-developed maxillipeds, and caudal rami whose length does not exceed five times their width. *H. thysanotus*, the first species treated here, since it was more intensively studied, has been described somewhat more fully. Descriptions of the females of the other species are intended to be read with reference to those preceding them; accounts of the males are, in addition, supplementary to the descriptions of their respective females. It is hoped that the illustrations, which represent in full the observations I have been able to make, will alleviate any inconvenience this arrangement may cause. A key to the American species is given on p. 165.

The terminology and abbreviations used are the same as those of a previous paper (Gooding, 1957), except that "protopodite" replaces "basipodal segments" and "element" replaces "articulated process"; "ornamentation" is restricted to "the complement of cilia and/or spinules of a particular structure"; and "armature" denotes "the complement of setae and/or spines of a particular structure." The last two definitions are, with permission, quoted from an unpublished thesis by Dr. Patricia Dudley. Terms such as "ventral," "anterior," and "right," when used in describing appendages or their parts, refer to these structures as they are oriented in the intact animal: e.g., "inner side of maxilliped" is the side nearest the animal's median longitudinal axis. For appendages which may change their orientation, the most usual position has been chosen for the description. Alternative terms are given in the legends to the figures. The phrase "burrow water" is used to refer to subsurface water accumulating in the hole created when digging for burrowing animals (in this case, callianassids).

To facilitate reference in the text, collections and collecting areas on the Pacific coast have been numbered thus:

C.1: Elkhorn Slough, Monterey Bay, California, lat. 36°49′ N., long. 123°16′ W., from *Callianassa californiensis* Dana, G.E. MacGinitie. For further details, see MacGinitie, 1935.

C.2: Tomales Bay, California, flats near Dillon Beach, lat. 38°15′ N., long. 122°58′ W., from 18 *Upogebia pugettensis* (Dana), J. W. Hedgpeth, June 1956.

C.3: Bodega Harbour, California, lat. 38°19′ N., long. 123°3′ W., muddy sand flats near Gaffney Ranch, from 19 *C. californiensis* and from 19 *U. pugettensis*, R. I. Smith, July 24, 1956.

C.4: Yaquina Bay, Oregon, lat. 44°38′ N., long. 124°3′ W., from 18 *U. pugettensis*, L. Aldrich, April 1957.

C.5: Willapa Bay, Washington, near Oysterville, lat. 46°33′ N., long. 124°0′ W., from 4 *C. californiensis*, H. Hetzel, May 5, 1957.

C.6: Kingston, Washington, a small lagoon about 1 mile southeast of the town, lat. 47°47′36″ N., long. 125°30′18″ W., muddy sand. I have found *C. californiensis* and a few *U. pugettensis* here.

C.7: Port Madison, Washington, lat. 47°42′ N., long. 122°31′ W.: *a*, a small lagoon in Fay Bainbridge State Park, soft muddy sand. I collected *C. californiensis* here on February 3, 1958. *b*, Seattle Yacht Club beach, muddy sand. *Callianassa gigas* Dana, *C. californiensis*, and *U. pugettensis* have all been taken here.

C.8: Bellingham Bay, Washington, lat. 48°45′ N., long. 122°45′ W., from 14 *C. gigas*, P. Wennikens, spring, 1956.

C.9: False Bay, Washington, lat. 48°29′ N., long. 123°4′ W. I have collected *C. gigas* and *U. pugettensis* from the southeast side of the mouth in muddy sand.

C.10: Hammond Bay, British Columbia, Piper's Lagoon, see Gooding, 1958.

C.11: Parksville, British Columbia, lat. 49°19′ N., long. 124°19′ W., soft sand, from 17 *C. californiensis*, Mrs. G. C. Carl (J. F. L. Hart), August 13, 1955.

No *Hemicyclops* were found in the following collections:

C. gigas: Humboldt Bay, California, lat. 40°48′ N., long. 124°12′ W., 1, J. Pearce, February 12, 1957.

C. californiensis: Collected by Mrs. G. C. Carl: Point Grey Beach, British Columbia, lat. 49°16′ N., long. 123°16′ W., 5, March 30, 1930. Brockton Point, British Columbia, lat. 49°18′ N., long. 123°8′ W., 1, November 29, 1929. Departure Bay, British Columbia, lat. 49°12′ N., long. 123°57′ W., 13, March 7, 1933; 23, April 26, 1933; 5, July 12, 1934. Witty's Lagoon, British Columbia, lat. 48°23′ N., long. 123°30′ W., 5, May 13, 1953; 3, June 10, 1953; 2, June 21, 1955. Cadboro Bay, British Columbia, lat. 48°27′ N., long. 123°17′ W., 9, January 9, 1956. Clam Bay, British Columbia, lat. 48°59′ N., long. 123°39½′ W., 4 ,August 22, 1957. Collected by W. Shapeero: Quilcene Bay, Washington, lat. 47°49′ N., long. 123°51′ W., 23, June 15–17, 1957. Collected by the Author: Burleigh Lagoon, Washington, lat. 46°23′ N., long. 123°38′ W., 6, June 7, 1956. C.7a: 6. Miller Bay, Washington, lat. 47°45′ N., 123°33′ W., 2, March 3, 1956. Mukkaw Bay, Washington, lat. 48°19′ N., long. 124°39½′ W., 3, May 15, 1956. Mission Bay, California, lat. 32°47½′ N., long. 117°14′ W., 9, March 28, 1956. C.5.

U. pugettensis: Collected by the author: C.10 (the Bay proper), 10, July 1956; numerous specimens also examined in the field, June 28, 1957. C.9, numerous specimens examined in the field, summers 1956 and 1957; also 3, August 1956. C.7b, 1, March 16, 1956. C.6, 1, February 11, 1956. Mission Bay, California (see above), 1, March 28, 1956. Collected by W. Shapeero: Quilcene Bay, Washington, 1, June 15–17, 1957.

Hermissenda crassicornis (Eschcholtz): Several specimens, mainly from pier at Friday Harbor Laboratories, San Juan Island, Washington, lat. 48°34′ N., long. 123°1′ W., summers 1956 and 1957.

Subsurface water: Golden Gardens City Park, Seattle, Washington, lat. 47°43′ N., long. 121°24′ W., 1,000 cc., from muddy sand with scattered stones, February 4, 1958.

The use of lactic acid in copepodological work has already been mentioned briefly (Gooding, 1957). This fluid is particularly suitable as a temporary mountant for small arthropods since it is directly miscible with most general preservatives, penetrates rapidly, clears satisfactorily, evaporates slowly, and has a low refractive index. It also renders specimens supple, so that dissection is facilitated. However, since it macerates the soft parts of the body, it cannot be used when the animals are required for study of the internal anatomy. The following procedure has proved very useful and should be applicable to small crustacea other than copepods.

A coverslip of sufficient size is fastened over the hole in a Bio-Plastic Micromount Holder (Ward's Natural Science Establishment, Inc., Rochester, N.Y.). Since this hole perforates the plastic slide, the two parts together form essentially a deep-well slide. The use of modelling clay for attaching the coverslip allows the latter to be removed easily whenever necessary. The specimen is then mounted in a small drop of lactic acid at the bottom of the "well" (i.e., centrally on the face of the coverslip nearest the slide). Staining is usually unnecessary and often undesirable but, if required, a weak solution of methyl blue in lactic acid may be used as the mountant.

When observations and drawings are being made, the slide should be placed coverslip uppermost so that the specimen is protected in a hanging drop within the cavity. If a coverslip of sufficient thinness is used initially, even an oil-immersion objective can be employed for examination, although, of course, some resolution is lost since the condenser cannot be oiled. The reverse position of the slide allows dissection and rearrangement of the animal or its appendages to be made with ease on the stage of a dissecting microscope. Any appendage which cannot be manipulated so as to show the relation of its parts satisfactorily can be removed to a standard microscope slide and flattened partially in a drop of lactic acid under a coverslip. Movement of the latter will usually produce the desired position (see the figures of "flattened" appendages included below, e.g., 5*d*).

Such temporary mounts will remain in good condition for long periods if protected from dust and if the lactic acid is renewed occasionally. Hoyer's medium (see Baker and Wharton, 1952, pp. 10–11, for formula) has proved satisfactory as a permanent mountant since specimens can be transferred to it directly from lactic acid.

A camera lucida was used in making all drawings. This device also permitted a simple and accurate method for comparing a series of specimens of one species. Drawings of the copepod first examined

were viewed simultaneously with the images of later mounts similarly oriented through the appropriate combination of lenses. Scales of magnification for each of the lens combinations used were drawn from a stage micrometer. The method for stereoscopic microscopy described by Galbraith (1957) proved very helpful in determining the shape and relations of appendages.

Among the many persons and agencies who have assisted me from time to time, I wish to thank particularly Dr. Paul Illg for much helpful discussion, suggestions, and encouragement during all phases of this work; Drs. Ernst Florey and K. L. Osterud for their critical reading of the manuscript; Drs. Fenner A. Chace, Jr., and Thomas E. Bowman of the U.S. National Museum for arranging the loan of material from the National Museum collections; and several others named in the text for supplying me with specimens either of copepods or of their hosts and information. The State of Washington, through Dr. Illg, provided support for part of the work and some facilities.

Genus *Hemicyclops* Boeck

Hemicyclops Boeck, 1873, p. 42; etc.

Of the seven species of *Hemicyclops* previously described from North and South America, three are considered valid and one doubtful; two new ones are added. Although very few specimens of each species have been examined, the small amount of variation between individuals of a particular form has made it possible to be somewhat more definite on points of specific discrimination than the evidence available might seem to favor. The following morphological characters are considered to have taxonomic value in differentiating the species discussed: the nature of the genital segment in the adult female; the ornamentation of the antenna and its elements; the terminal armature of the mandible, maxilla and maxilliped; the ornamentation of the labium; the setal formula of the swimming legs; the relative lengths of elements on the fifth legs; the presence (and nature) or absence of sixth legs; and the modification of setae on the caudal rami. These characters permit us to divide the American species into two well-defined groups: the first comprising *thysanotus* (and *purpureus* if it occurs in these waters, see p. 176), the other including *adhaerens*, *subadhaerens*, *arenicolae*, and probably *elongatus*. (Lack of knowledge about the mouthparts and maturity of the only specimen available precludes any completely certain disposition of *elongatus*.)

It is difficult at this stage to determine whether the second group represents a polytypic species or a superspecific complex. I have preferred the latter alternative because the morphological differences between its members are approximately equivalent to those currently

used (Humes, 1949, 1957) in characterizing the species of *Clausidium*, a genus belonging to the same family, and the ecological differences are much greater; also with respect to *adhaerens* and *arenicolae*, there is some evidence for sympatry, although no intermediates occurred among the specimens that I have examined.

This superspecies would be characterized mainly by the separation between genital and first abdominal segments and the well-developed sixth legs in the adult females; the reduced mandibular setation and presence only of simple terminal elements on the maxilla and of setulose exopod spines on all the swimming legs in both sexes; and the attenuated "scaly" tip of the male maxilliped. Its members are known only from the New World but appear morphologically quite similar to the species of *Giardella* that have been reported from the coasts of France and England.

The species discussed range from forms found free-living (*adhaerens*) to those which, under natural conditions, seem to remain in contact with their hosts (*thysanotus* and *elongatus*?). Intermediate between these extremes are associates which may inhabit the burrow but seldom stray onto the body of the host (*subadhaerens*), or apparently are equally common in the one as on the other (*arenicolae*). Further work is needed to determine whether species of the first type are really independent and, for forms associated with other animals, what are the relations of copepod and host.

A feature of the species *thysanotus* and *subadhaerens* (the only ones examined alive) is the presence, mainly in the prosome, of droplets of a red, oily-appearing material among the organs. It appears to be incorporated in the eggs, and to a lesser extent the spermatophores, and occurs in the nauplii. Such stored material is very characteristic of species of *Clausidium*, which are also associated with *Callianassa*. It is responsible for the bright red color of these copepods. Its presence seems not to depend on an association with callianassids, however, for Sars (1917) described a female of the apparently free-living *Hemicyclops purpureus* as having "bright red" ovarial tubes and ovisacs. These observations are consistent with what is known about carotenoid metabolism in copepods and other Crustacea and, if chemically of this nature, the substance probably has its origin in the organism's food (Fox, 1953). Thus, in species associated with *Callianassa*, it could presumably be derived from plant and/or bacterial matter, from the host's blood, or from the eggs of berried female mud shrimp.

The key below refers to the presently known species of *Hemicyclops* that I have examined from North and South America. It is applicable to the adults of both sexes but will probably also serve to distinguish immature specimens, at least to morphological group. The structure of the maxillipeds and the nature and position of the

sixth legs will most easily differentiate adult males from females. Dissection should not be necessary in following the key but use of a compound microscope and generally some preliminary clearing treatment (discussed on p. 162) will be essential.

1. Setulose exopod spines only on first leg; terminal segment of antenna very little longer than wide . . . . . **thysanotus** (p. 165)
   Setulose spines on exopods of all 4 swimming legs; last antennal segment more than 2 times as long as wide 2
2. Antenna with 2 large, elliptical patches of fine spinules on inner side of second and third segments; distal podomere of fifth legs without spinules on sides. **arenicolae** (p. 188)
   Antenna without spinules as above; distal podomere of fifth legs with some spinules on sides 3
3. Caudal rami more than 4 times as long as wide; body more than 2.7 mm. in length . . . . . **elongatus** (p. 184)
   Caudal rami less than 3 times as long as wide; body less than 2.5 mm. in length 4
4. Innermost spine on distal segment of fifth legs about equal in length to adjacent seta; ventral spine on maxilliped with 2 denticles on anteroventral surface . . . . . **adhaerens** (p. 176)
   Innermost spine on distal segment of fifth legs shorter than adjacent seta; ventral spine on maxilliped with 3–5 denticles on anteroventral surface . . . . . **subadhaerens** (p. 181)

Hemicyclops thysanotus Wilson

FIGURES 1; 2; 3,*a–c*

Hemicyclops thysanotus Wilson, 1935, pp. 783–785, pl. 28, figs. 41–52.—Light and Hartman, 1937, pp. 179–180, pl. 12, figs. 3–4.—Nicholls, 1944, pp. 44, 49.—Sewell, 1949, pp. 67, 69.

Hemicyclops callianassae Wilson, 1935, pp. 782–783, pl. 27, figs. 25–35.—Light and Hartman, 1937, pp. 179, 180.—Nicholls, 1944, pp. 45, 49.—Sewell, 1949, p. 67.

Hemicyclops pugettensis Light and Hartman, 1937, pp. 179, 180, 181–182, 182, t.-figs. 12–20, pl. 12, figs. 5–6.—Nicholls, 1944, pp. 45, 49.—Sewell, 1949, pp. 67, 68, 69.—Gooding, 1958, p. 699 (part).

TYPES: "A single female bearing ovisacs and a male . . . from the outside surface of the eolid, *Hermissienda* [sic] *crassicornis*, in Elkhorn Slough, Monterey Bay" (Wilson, 1935), USNM 64063, here considered syntypes.

The designated types for *callianassae* were "a single female with attached male" (Wilson, 1935), USNM 60432. Of these only the male syntype appears to be still in existence (letter from Dr. T. E. Bowman, February 25, 1958). *H. pugettensis* was stated by Light and Hartman (1937, p. 182) to be based on a single specimen, but the catalog number that they quote (USNM 71678) comprises a (syntypic) series including females and males. There is no record of a holotype in the U.S. National Museum.

MATERIAL EXAMINED: From *Hermissenda crassicornis:* C.1 (see p. 160): 1 female, 1 male, syntypes of *thysanotus*. 5 females, 3 males,

paratypes of *thysanotus*, USNM 64064. A slide, containing the parts of a dissected female, labelled "*Hemicyclops thysanotus*—Paratype." 1 female from body surface, August 20, 1927, identified by S. F. Light, USNM 90937, dissected.

From *Callianassa californiensis:* C. 1: 1 male syntype of *callianassae*. 12 females, 6 males, 6 juveniles, paratypes of *callianassae*, USNM 60433, all from gill chamber. Slide of a dissected female, labeled "*Hemicyclops callianassae*—Paratype." 20 females, 11 males from eggs, Wilson's *thysanotus* (figures 2*a–b*, *d*, *f–l*, and 3*a–c*, are based on a female and figure 1*a–d* (labrum), *e*, *g–p*, and *r* on a male of this lot). C.3: 1 female from debris in bottle.

From *C. gigas:* C.9: 12 females, 1 male from body surface, B. Blanchard, June 1936, syntypes of *pugettensis* (discussion of type locality in Gooding, 1958, p. 699). Slide of a dissected female labelled "*Hemicyclops pugettensis*—Type," Illg's collection. Several specimens from gill chamber and body surface, summers of 1956 and 1957, e.g., 2 females, 2 males from 2 hosts, July 27, 1957; 6 females, 2 males from 3 hosts, August 21, 1957; figure 2*c*, *e*, and *h*, was drawn from a female and figure 1*d* (labium), *f*, and *g* from a male, both of the first lot. C.7b: Several specimens from gill chamber and body surface, 1955–58, e.g., 19 females, 9 males, 1 juvenile from 3 hosts, March 16, 1956; 54 females, 27 males, 9 juveniles from 5 hosts, February 3, 1958. C.8: 4 females, 1 juvenile from debris in bottle.

From *Upogebia pugettensis* (a host of this copepod not previously mentioned in the literature): C.2: several specimens between gill filaments and in debris (one female was dissected). C.3: 9 females, 12 males, 10 juveniles from debris in bottle. C.4: 121 females, 88 males, 8 juveniles from debris in bottle; twenty specimens of each sex have been deposited in the U.S. National Museum, No. 101368.

Redescription of the female: Body 2.0 mm. in length (mean of 10 specimens, range 1.74–2.44 mm.); clearly divided into wide prosome (0.9 mm.; 0.77–0.97 mm.) and narrower urosome. Color in life (re-

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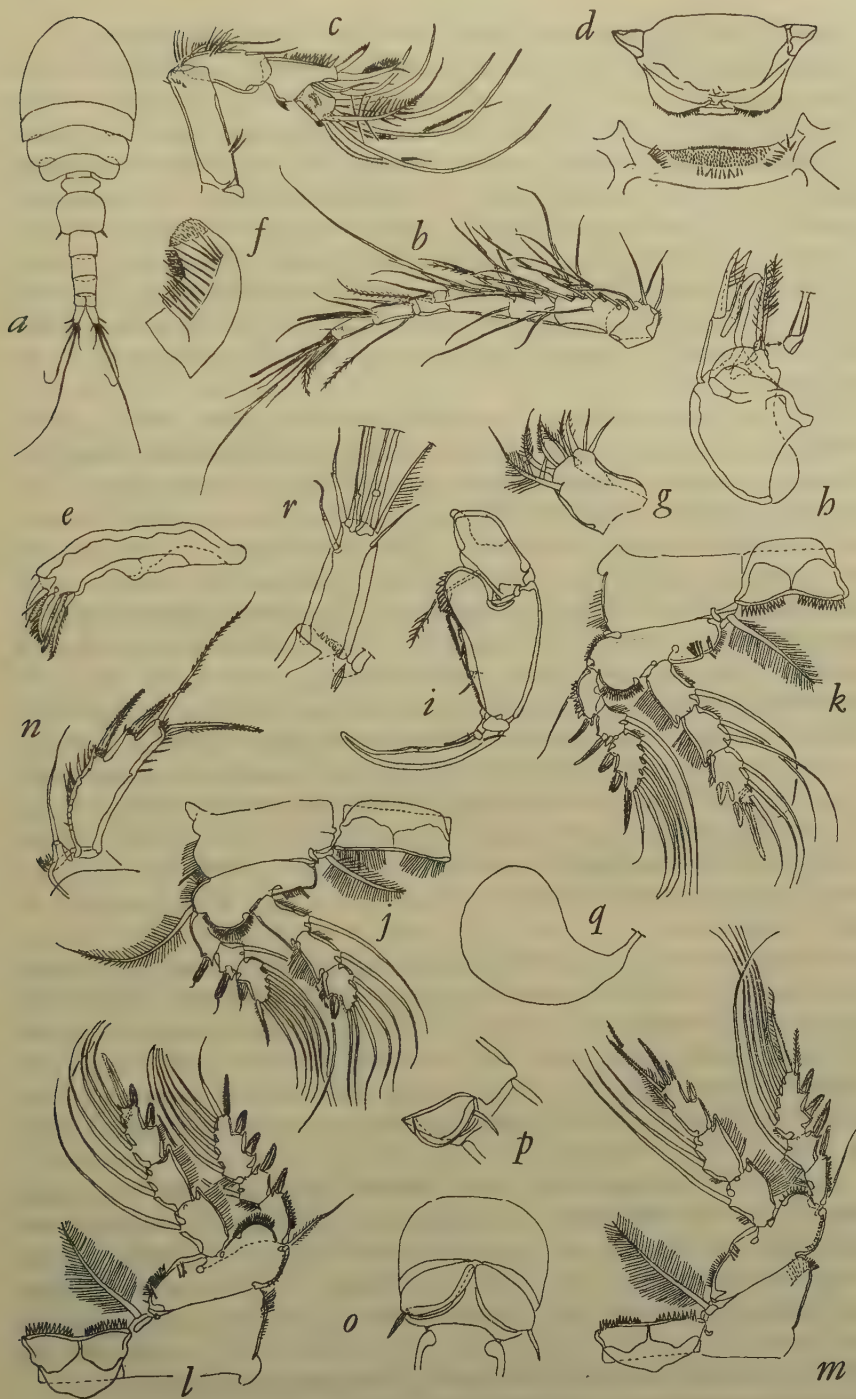
Figure 1.—*Hemicyclops thysanotus* Wilson, male: *a*, Habitus, dorsal aspect. *b*, Right antennule, dorsal (anterior) view. *c*, Right antenna, dorsal (posterior) view. *d*, Labrum in dorsal, labium in ventral view. *e*, Right mandible, ventral (posterior) view. *f*, Right paragnath, ventral (posterior) view. *g*, Right maxillule, dorsal (posterior) view. *h*, Left maxilla, dorsal (anterior) view, with detail of base of setule-bearing seta from a different aspect. *i*, Right maxilliped, ventral (posterior) view. *j*, Right first swimming leg with coxal plate, ventral (anterior) view. *k*, Right second swimming leg with coxal plate, ventral (anterior) view. *l*, Right third swimming leg with coxal plate, ventral (anterior) view. *m*, Right fourth swimming leg with coxal plate, ventral (anterior) view. *n*, Right fifth leg, ventral view. *o*, Ventral view of genital segment showing position of sixth legs. *p*, Left sixth leg, lateral view. *q*, Spermatophore (somewhat swollen) expressed from genital segment. *r*, Right caudal ramus, dorsal view. Scale A (fig. 2) applies to *a*: D to *b* and *i–m*; E to *c–d*, *g–h*, and *n–r*; F to *e*; and G to *f*.



For Explanation, See Opposite Page

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flected light) opaque white with red areas, mainly in the prosome around or coloring the oviducts, which tend to give a general reddish appearance on the whole body when viewed with the naked eye; fifth legs and caudal rami occasionally brown; eye and ovisacs bright red.

Prosome comprising a cephalothorax, with no trace of division between cephalosome and first pedigerous somite, and 3 metasomal segments whose terga are usually imbricate, with square or rounded corners. Prosome ovate but posteriorly truncate in dorsal outline, flattened in side view. Eye of the usual naupliar type. Rostrum (fig. 2*b*) a small fold, apparently in tergum of cephalothorax, producing this ventrally between bases of antennules. Postoral protuberance inconspicuous.

Urosome 5-segmented. Largest the genital segment, which almost certainly represents a complex of 2 somites, the boundary between them represented ventrally and occasionally in dorsal view by a thickened ridge. (Light and Hartman, 1937, give a very good picture of this segment in their figure 12. This figure shows the structure of the anterior part of the segment—i.e., genital somite proper—with its 2 pairs of small lateral expansions. The dorsal anterior pair of expansions are often joined along the dorsal surface by a thickened strip and make the anterior part of the segment wider than the posterior region—i.e., first abdominal somite.) Paired oviducal openings ventrolateral on anterior corners of genital segment. Ovisacs with numerous eggs, usually reaching ends of caudal rami, narrowly cylindrical. Three free abdominal segments, the last here termed the anal segment and carrying a row of fine spinules ventrally along each side of distal border near midline. Anus dorsal, without distinct anal operculum; oval-shaped area in figure 2*l* having a very thin integument.

Caudal rami more than 3½ times as long as wide; bearing 4 terminal setae and an outer lateral and an inner dorsolateral seta, all distally placed. Outermost terminal and usually outer lateral seta comprised of a basal shaft, ending in a small spiniform projection on one or both sides, and a terminal "flagellum" whose thickening is broken up into transverse rings. Two longest setae with usual "jointed" attachment at base.

Antennule 7-segmented. Attachment of basal segment to ventral exoskeleton of head region at right angles to plane of projection of remainder of appendage. Appendage in life carried perpendicular to sagittal plane of body. Last 3 segments slightly narrower than and their axis at an angle to preceding 4. Setation: 4 on first, 15 on second, 6 on third, 3 on fourth, 4 on fifth, 2 and an aesthete on sixth, 7 and an aesthete on seventh. Long setae on fourth and terminal segments very obvious. One seta on second and one on fifth

segment the only ones completely ciliated but several with cilia near tips. Almost all setae with thickening in transverse rings. Aesthetes narrow and rather inconspicuous, with basally thickened walls.

Last 3 segments of tetramerous antenna typically bent at right angles to first and lying near mouth region. (Subsequent terminology with reference to this position.) Fourth segment offset in fashion typical of clausidiids; almost quadrate; bearing terminally on dorsal side a seta, with long heavy cilia, in a notch on the outer edge 2 spinulose setae, and 4 curved setae inserted linearly along width of distal border between the two groups. Two proximal of the 3 "comb rows" of spinules on this segment difficult to see. Outer corner of third segment produced distally for more than half length of fourth; 2 characteristically ornamented spines at its tip; a curved seta and another shorter seta in recess between this projection and insertion of fourth segment. Surface thickening of 5 curved setae on antenna irregular from region of initial curvature to tip; the latter either notched (in the longest 2) or finely toothed on the inner side. Other ornamentation and armature of appendage as shown in figure 2*d*.

Mouth region (fig. 2*e*) and adjoining appendages closely compacted in typical poecilostome fashion, their arrangement very similar to that of *H. australis* (Nicholls, 1944, fig. 21) or *purpureus* (Sars, 1917, pl. lxxxi, "Or. area"). Labrum protruding from ventral body surface; posterior border straight, its median portion with 2 rows of small denticles set one above the other. Each flange forming posterior corner of labrum with 2 rows of larger denticles; upper row turning dorsally (i.e., toward mouth) at its inner end. Sides of labrum nearest mouth cavity flaring sharply away from a median "prow" which overhangs mouth. Labium a flat rectangular surface delimited by thickenings in ventral exoskeleton of head region; its anterior half beset with rows of denticles pointing toward mouth. Between latter and labium is a square area, the roof of the mouth cavity, clothed in cilia and rising medially into a bilobed prominence. Paragnaths inserting laterally on roof of mouth cavity anterior to labial corners; thick, comma-shaped flaps profusely ciliated; oriented nearly at right angles to surface beneath, with tips approaching each other on midline.

Mandible with strongly thickened triangular base. Body of appendage curves toward midline, backwards and upward, fitting under sides of labral "prow" so that tip lies in mouth cavity. Terminal armature a heavy, curved element, a spinulose blade, and 2 setae with strong cilia; all articulated. Dorsal element dentate along one edge, with an incompletely toothed ridge at an angle on anterior side.

Flaplike maxillule distally bilobed: smaller lobe with 3, larger (outer) with 5 setae, majority strongly ciliated and with transverse

rings of thickening. An angular projection on dorsal face near base of inner side. Exoskeletal thickening of ventral body surface around base continuous with that around base of mandible but appendages not confluent and thus considered separate entities. Maxillule curves posteriorly away from ventral surface and toward midline, thus often obscuring tip of maxilla in a ventral view of animal.

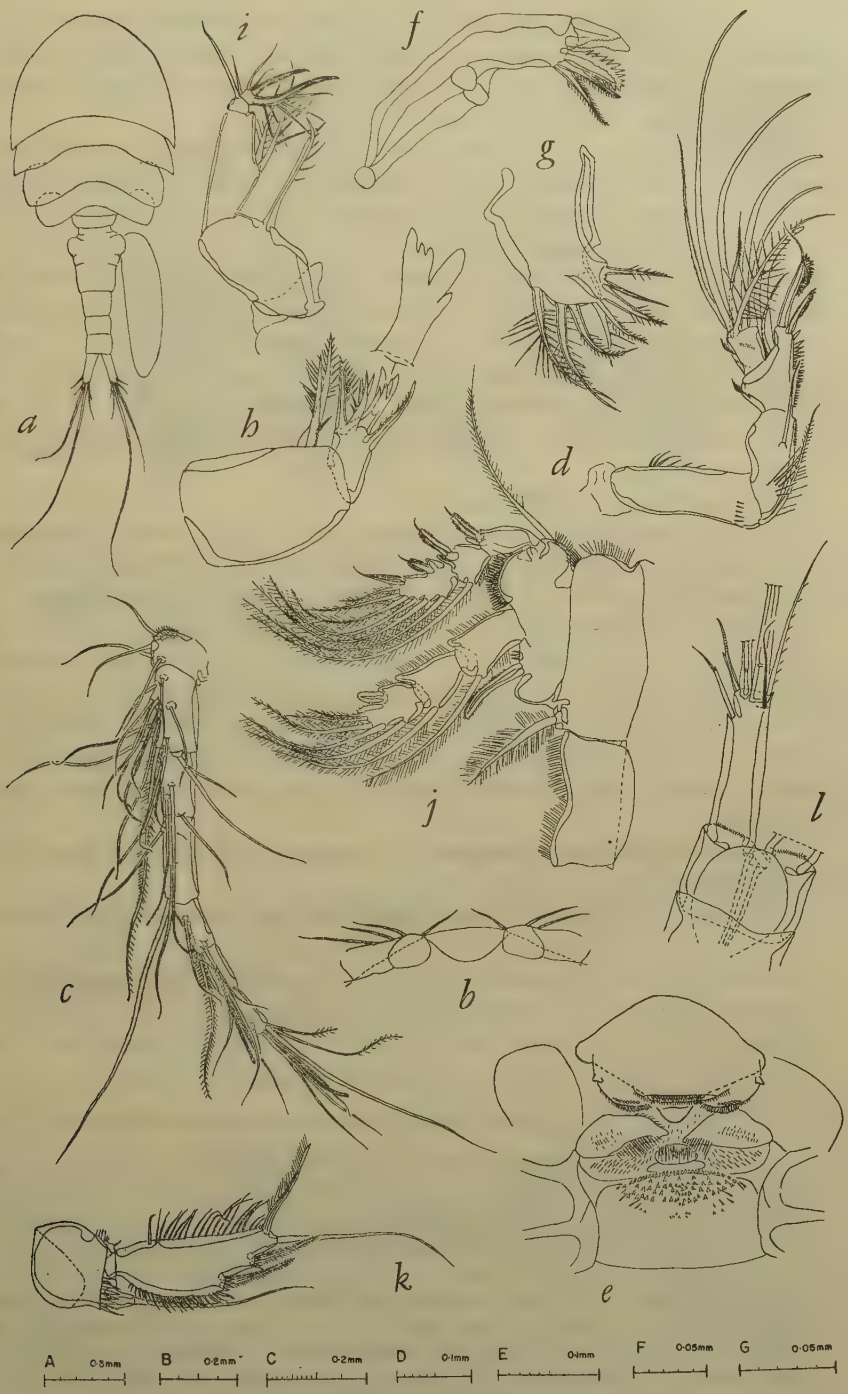
Maxilla 2-segmented; first much inflated, bearing near distal end of its inner face 2 thick strongly ciliated setae, the posterior (larger) with a setule on its base. Armature of second segment a complex element (see fig. 2*h*) having 2 major curved branches, one with a subsidiary ramus anterodorsally near its origin, other with 2 of these on its lower side; a dorsal and a ventral spine, both with strong cilia; and, alongside the complex element, a third spine (possibly with a bifid tip) bearing long flattened cilia.

Maxilliped 4-segmented; third and fourth segments subequal. Posterior seta on first segment bare. Third segment with one long seta. Terminal segment prolonged into a long, curved process with strong cilia (this process almost certainly represents a fused element whose articulation with the segment has been lost); ventral to this process is a ciliated spine bearing a seta on its anterior face and 2 setules (not shown in fig. 2*i*) on the anteroventral corner; the segment also carries 2 setae, one on the outer and one on the posterior surface.

Swimming legs all with 2 segmented protopodite and 2 trimerous rami; exopodite inserted on side of basipodite and thus appearing much shorter than endopodite. Coxal plates short and deep; first with cilia on distal edge but others having spinules here. Armature as follows:

	Protopodite				Endopodite						Exopodite					
	1		2		1		2		3		1		2		3	
	Si	Se	Si	Se	Si	Se	Si	Se	Si	Se	Si	Se	Si	Se	Si	Se
P1	1	--	I	1	1	--	1	--	5	I	--	I	1	I	6	II
P2	1	--	--	1	1	--	2	--	3	III	--	I	1	I	6	III
P3	1	--	--	1	1	--	2	--	3	III	--	I	1	I	6	III
P4	1	--	--	1	1	--	2	--	1	IV	--	I	1	I	7	II

FIGURE 2.—*Hemicyclops thysanotus* Wilson, female: *a*, Habitus, dorsal aspect. *b*, Rostrum between basal segments of antennules, ventral view. *c*, Left antennule, dorsal (anterior) view. *d*, Left antenna, dorsal (posterior) view. *e*, Oral area (without appendages), ventral view. *f*, Right mandible, ventral (posterior) view. *g*, Right maxillule, ventral (anterior) view. *h*, Right maxilla, dorsal (anterior) view, with detail of compound element from different aspect. *i*, Right maxilliped, ventral (posterior) view. *j*, Right first swimming leg with coxal plate, ventral (anterior) view. *k*, Right fifth leg, ventral view. *l*, Right caudal ramus, dorsal view. Scale A applies to *a*; C to *b*; D to *c* and *j–l*; E to *d–e* and *h–i*; and F to *f–g*.



For Explanation, See Opposite Page

Only the 3 spines nearest base exopodite of first swimming leg with a terminal setule. Base of most median seta on third endopodite segment of legs 2–4 with a group of 3 or 4 strong cilia. Other ornamentation as shown in the figures.

Fifth legs 2-segmented; inserted on ventrolateral corners of thoracic segment. First podomere small and square, almost hidden in dorsal view by a lateral projection (which shows remnant of tergum) of thoracic segment; its seta, borne on a papilla on outer distal corner, nearly as long as terminal segment. Latter lamellar; with a slight outward and upward curve; bearing 2 spines set stepwise on outer edge of distal half, a long seta on a small papilla and a finely ciliated spine terminally. Terminal segment ornamented with spinules on outer and strong cilia on inner edge. (Several specimens from Puget Sound region have also a "sunburst" of well-developed cilia near base on ventral side.)

Sixth legs apparently absent.

Redescription of the male: Body 1.53 mm. in length (mean of 6 specimens, range 1.50–1.54 mm.) and 0.65 mm. (0.64–0.70 mm.) wide; paler in color than female. Urosome longer in proportion to prosome and the latter more ovate. Genital segment not compound so that urosome 6-segmented. Paired genital ducts opening ventrolaterally in posterior half of genital segment. Spermatophores (fig. 1*q*) small kidney-shaped structures with a short stalk. (When attached to the female, they are rather smaller than indicated by the figure.) Caudal rami shorter in proportion to their width than those of female.

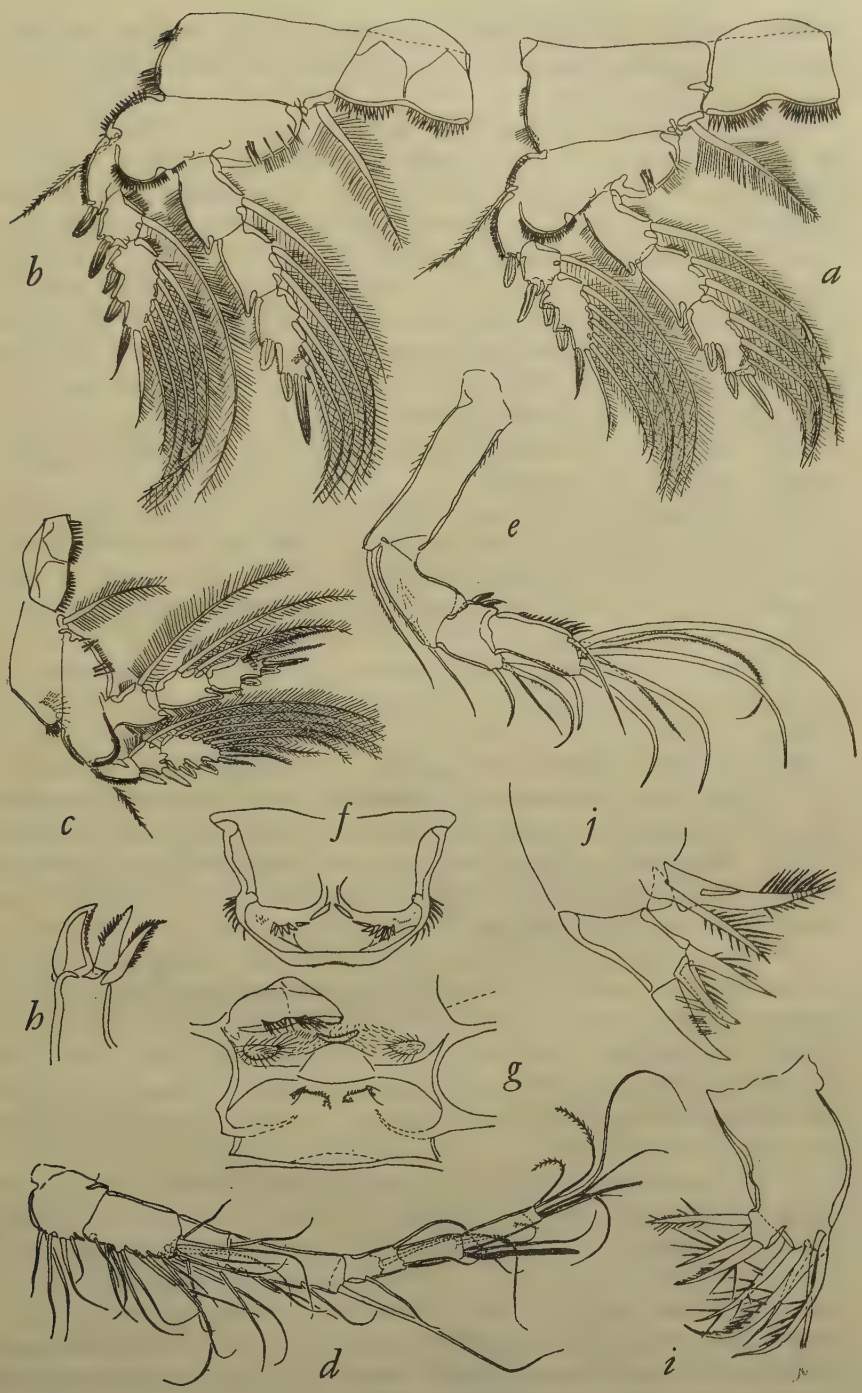
Ciliated seta on second segment of antennule not as well-developed as in female.

Antenna occasionally without patch of spinules on inner distal corner of second segment.

Posterior limit of labium difficult to distinguish; denticles present in female here reduced to small spinules or cilia.

Mandible and maxillule very similar to female condition, but former may apparently lack second seta on one or other side.

Figure 3.—*a–c*, *Hemicyclops thysanotus* Wilson, female: *a*, Right second swimming leg with coxal plate, ventral (anterior) view. *b*, Right third swimming leg with coxal plate, ventral (anterior) view. *c*, Right fourth swimming leg with coxal plate, ventral (anterior) view. *d–j*, *Hemicyclops adhaerens* (Williams), female: *d*, Left antennule, dorsal (anterior) view. *e*, Right antenna, ventral (anterior) view. *f*, Labrum from ventral side but with microscope focused so that dorsal structures are apparent. *g*, Labium, right paragnath and part of roof of mouth cavity, ventral view. *h*, Apex of left mandible, dorsal (anterior) view. *i*, Left maxillule, ventral (anterior) view. *j*, Distal half of right maxilla, dorsal (anterior) view (flattened, setule-bearing seta partly detached from base). Scale C (fig. 2) applies to *c*; D to *a–b*; E to *d*; F to *e–g*; and G to *h–j*.



For Explanation, See Opposite Page

Most ventral seta on second segment of female maxilla replaced here by a heavily sclerotised but unornamented hook which is confluent with the segment.

Maxilliped similar in basic plan to that of female but very different in appearance. Only 1 seta on basal segment; 2 on second, which is heart-shaped with several rows of spinules (the largest near base of segment), much reduced in size and ornamentation and widely separated. Terminal segment extended into a long, thick, curved process bearing 3 setae as shown in the figure. (Longest of these setae is very closely appressed to and often seems partially fused with basal region of process; this part may represent instead of a seta a partially separated membrane. It is difficult to homoligize the armature of this segment with that found in the female.)

Only change in armature of swimming legs is loss of spine on inner distal margin of first basipodite.

First podomere of fifth legs completely fused with thoracic segment but its seta and ornamentation remaining. Bases of this pair of legs connected ventrally by a thickened strip. Strong cilia on inner edge of terminal segment in female replaced by fewer spinules here and these more distal in position.

Sixth legs form paired flaps covering, in ventral view, most of posterior half of genital segment; a curved spine on each ventrolateral corner.

Remarks: My observations support neither the differences educed by Wilson (1935) between *H. callianassae* and *thysanotus* nor the characters stressed as diagnostic for *pugettensis* by Light and Hartman (1937). Accordingly, the three species are here considered identical. Since *pugettensis* is clearly a junior synonym, the valid name must be selected from the other two.

H. callianassae and *thysanotus* were described in the same publication (Wilson, 1935); the former, since it was listed first and described in equal detail, would normally become the species name. However, I propose to take advantage of "the principle of the first reviser," reinstated in 1953 (International Commission on Zoological Nomenclature, pp. 66–67), and examine the problem posed in this instance by *Giardella*.

As mentioned earlier (p. 160), the genus *Giardella* Canu, whose type species (by monotypy) is *G. callianassae* Canu, 1888, is very closely related to *Hemicyclops*. In studying the literature, I have come to the conclusion that it may eventually be desirable to expand the generic concept of *Hemicyclops* so as to include this species. If page priority is strictly applied in the case of Wilson's form, however, and *callianassae* is chosen, any later merging of *Giardella* with *Hemicyclops* would make it necessary to alter the name of his species. I believe that there

is thus sufficient reason for considering the "other things" not to be "equal" (the present wording of Article 28 of the Rules of Zoological Nomenclature), and hence in the interests of stability, I have preferred *thyanotus* to *callianassae* for designating this Pacific Coast species.

It should be noted that MacGinitie's order of listing (1935) cannot be used to support this choice (i.e., by dating Wilson's species from his paper) since, although technically the first mention of *thysanotus* and *callianassae* in the literature, his names per se must be considered nomina nuda.

H. thysanotus seems very close to *thomsoni* (Canu) and to *dilatatus* Shen and Bai. For the present, however, the following characters will serve to diagnose the species: the fusion of first abdominal and genital somites; the ornamentation of the antenna, particularly the heavy ciliation on one of its terminal setae; the armature of the last maxillar segment; the presence of setule-bearing spines on the exopodite of the first swimming leg only; the shape and ornamentation of the distal segment of the fifth legs; and the modified setae on the caudal rami. Specimens in the northerly part of its range are, as might be expected, larger and their appendages, particularly with respect to armature and ornamentation, often better developed; but no meristic differences among specimens have been observed. Nor could I find evidence for the existence of host-specific forms.

Distribution: The species is known to range from San Juan Island, Washington, to Monterey Bay, California, and occurs on four hosts, the nudibranch *Hermissenda crassicornis* and the thalassinids *Callianassa gigas*, *C. californiensis*, and *Upogebia pugettensis*. All of these hosts are common within the copepod's entire range, but there are some puzzling irregularities in its geographical distribution on them. From Oregon south, *thysanotus* seems to be abundant on *Upogebia* and, in California (MacGinitie, 1935; MacGinitie and MacGinitie, 1949), on *Hermissenda* and *C. californiensis;* yet over a period of 2½ years of collecting, I have not found specimens on any of these three in the Puget Sound region. The statement in Gooding (1958), that *thysanotus* occurred on *C. californiensis* at Nanaimo was based on a misindentification. Locally, but apparently not in California, it is abundant on *C. gigas*.

The ecological factor common to *Hermissenda* and callianassids as habitats is also difficult to visualize. In association with the latter animals, *thysanotus* is generally found in the gill-chamber but may also occur on the surface of the body. Although it may leave its host for a short time when the latter is placed in a dish of seawater, the copepod has never been found in water from the burrows. On *Hermissenda*, *thysanotus* occurs on the body surface (MacGinitie). Nothing is known about its feeding habits; MacGinitie (1935) suggests that it

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may remove debris from among the eggs of *Callianassa* and, if so, it may also help to keep the gill-chamber clean. It is hoped that further collecting and possibly experimental work will make clear the host preferences and relations with the host of this copepod.

Immature specimens occasionally are found in debris from preserved *Callianassa;* the smallest corresponds to the second copepodid stage in other copepods. It is possible that the early stages are free living and dispersive, development only being completed when a host is found.

Hemicyclops purpureus Boeck

Hemicyclops purpureus Boeck, 1873, p. 42; etc.

This species was reported by Wilson (1936, pp. 368, 375) from plankton collected in Fox Channel (lat. 66–67° N., long. 80° W.), northern Canada, by Captain R. A. Bartlett in August 1933, but no diagnosis or figures are given. Taking into account both the restricted range otherwise known for *purpureus* (coasts of Norway, Sweden, and possibly Scotland) and Wilson's lapses in descriptions of other species in this genus, I do not think that his record can be accepted at present entirely without question. If correct, however, his record would be of great interest, and it is hoped that further collections in that area will confirm his identification. Such confirmation is unfortunately impossible now since the specimen (or specimens) that he examined are not in the U.S. National Museum, where the Bartlett collection was deposited (letter from Dr. T. E. Bowman, November 21, 1957).

Because I have not examined specimens, no other account of *purpureus* is given here and it is not included in the key. On the basis of Sars' redescription (1917), the species apparently differs from *thysanotus* in the proportions of the caudal rami and of the fifth legs and in the armature of the third segments of both rami on the fourth swimming leg. It may readily be distinguished from *adhaerens*, *subadhaerens*, *elongatus*, and *arenicolae* by the presence in these of the following: 6-segmented urosome, reduced mandibular setation, 4 simple terminal elements on the maxilla, shorter maxillipedal process (of the female) and different armature of the swimming legs.

Hemicyclops adhaerens (Williams)

FIGURES 3, *d–j*; 4

Lichomolgus adhaerens Williams, 1907, pp. 75–76, pl. 2.

Hemicyclops adhaerens, Wilson, 1932a, pp. 345–346, fig. 206.—Light and Hartman, 1937, pp. 179, 180.—Sewell, 1949, p. 67.

Hemicyclops americanus, Wilson, 1932b, pp. 44–45, pl. 5, figs. A–H.—Light and Hartman, 1937, pp. 179, 180.—Nicholls, 1944, p. 45.—Sewell, 1949, pp. 67–69.

TYPES: Williams (1907) stated that his specimens were from "Wickford, very abundant under small stones between tides." He

did not designate a type nor mention where his specimens were deposited.

H. americanus was based (Wilson, 1932b) on a holotype which, together with one paratype, was deposited in the U.S. National Museum. The vial of his specimens received from there contained a "type" label (among others), which reads "Holotype Cat. No. 58563/To be selected/Paratype Cat. No. 63420," and two smaller unlabeled vials, each with a single copepod. There is no indication which of these Wilson intended to designate as the holotype, and hence they are here considered syntypes of *americanus*.

Specimens examined: Wickford, Rhode Island, 1 female from washings of intertidal rocks, G. M. Moore and N. W. Riser, June 13, 1957; this topotype was dissected and used for making all the figures; the slide has been deposited in the U.S. National Museum, USNM 101729. Chesapeake Bay, Maryland, 2 females from bottom tow, U.S. Bureau of Fisheries, Station R′ (off Cove Point), R. P. Cowles, June 2, 1921, syntypes of *americanus* (one was dissected).

Redescription of the female: Body very similar in appearance to *thysanotus* but genital segment not fused with first abdominal so that urosome is 6-segmented. Length 1.58 mm. (mean of 3 specimens, range 1.43–1.67 mm.); width of prosome 0.64 mm. (0.57–0.69 mm.). Genital segment roundish; genital openings median and lateral. Ovisacs (one specimen) proportionately wider than those of *thysanotus* but only reaching distal border of second abdominal segment. Lines of spinules on distal border of anal segment much stronger than in *thysanotus* and displaced outward.

Caudal rami 2–2½ times as long as wide, with relatively long inner dorsolateral seta and a tiny element (which may represent a rudimentary seta) near base on outer side. No setae modified as in *thysanotus*.

Antennule like that of *thysanotus* except for setation on first 2 segments (5 on first, 14 on second); long setae on second, fourth, and terminal segments relatively shorter and setae on second and fifth segments apparently lacking cilia.

Antenna with fourth segment elongate and distal corner of third hardly produced. Armature similar to *thysanotus* condition but spines on outer distal corner of third segment replaced by setae and these, together with that on first segment, with reduced ornamentation; isolated seta in terminal position bare. Curved setae with region of irregular surface thickening reduced to short length near position of greatest curvature and very thin flange often present here; tips all with notch some distance from the end. No patch of spinules on outer corner of second segment; third with 2 "comb rows" on inner side; last with only a row of spinules.

A single row of spinules on posterior border of labrum. Paragnaths of somewhat different appearance from those of *thysanotus*. Anterior median portion of labium flowing forward to merge with roof of mouth cavity; ornamentation on its surface confined to 2 irregularly curved rows of denticles. Two ciliated lobes on roof of mouth cavity just posterior to insertion of paragnaths.

Mandible with curved element and blade but only 1 seta; terminally curved element lacks incomplete roothed ridge, dentations on edge stronger.

Maxillule very similar in plan to that of *thysanotus* but angular projection poorly developed and more dorsal in position. Some differences in relative size and ciliation of setae.

Setule-bearing seta on first segment of maxilla larger than the other; terminal armature of second segment (ventral to dorsal) a strong curved spine, 2 smaller ones almost side by side—the anterior notched at its tip, the other strongly ciliated—and a longer spine with strong cilia.

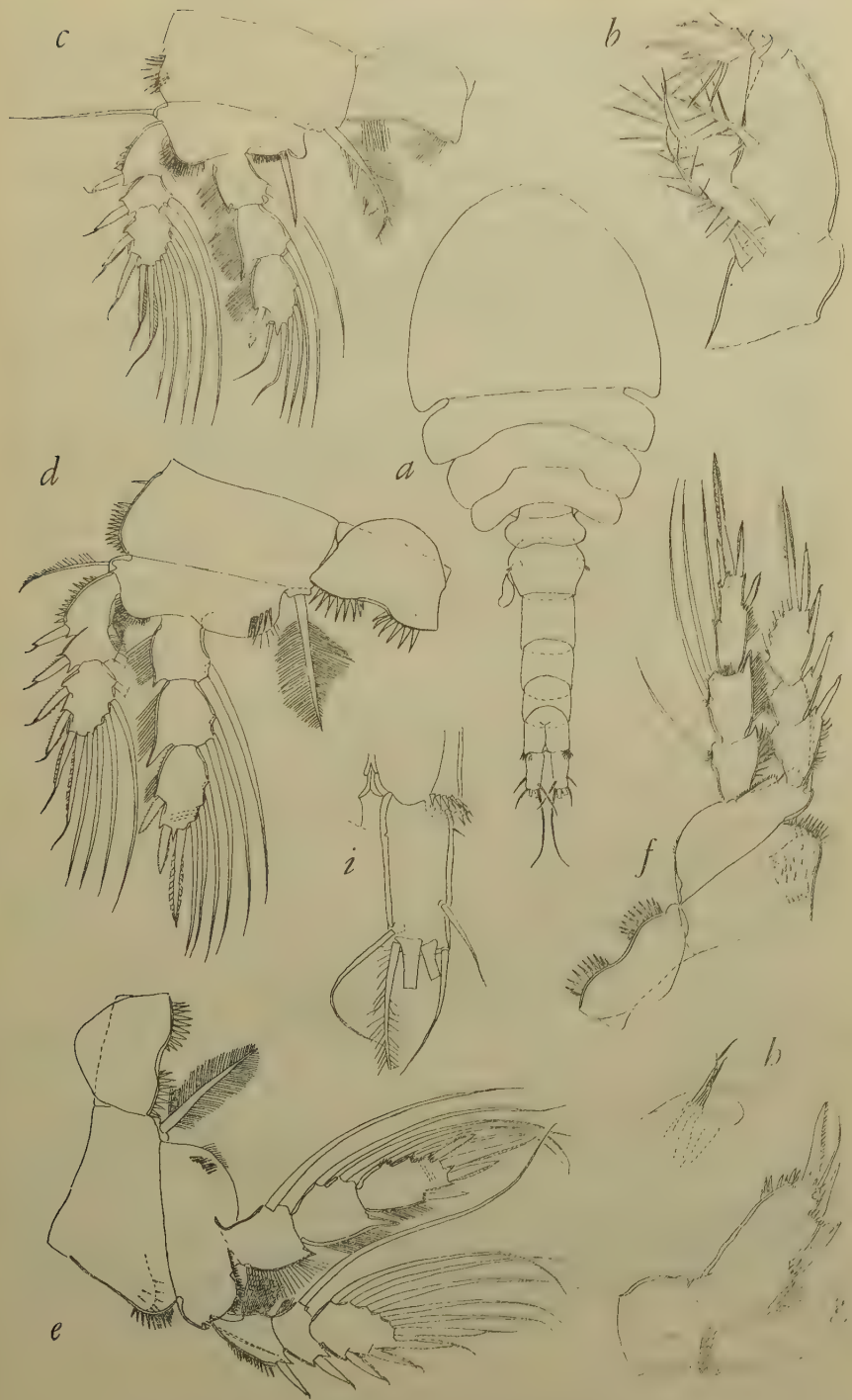
Maxilliped with no seta on third, 2 on terminal segment: longest seta on anterior side, other on base of dorsal process. (It is difficult to homologize the smaller seta with any on the *thysanotus* maxilliped.) Ventral spine bearing only 2 spinules on anteroventral surface and terminating in a setule inserted near tip. Both setae on first segment with very long cilia.

Swimming legs similar to those of *thysanotus* except in armature, which is:

	Protopodite				Endopodite						Exopodite					
	1		2		1		2		3		1		2		3	
	Si	Se	Si	Se	Si	Se	Si	Se	Si	Se	Si	Se	Si	Se	Si	Se
P1	1	--	I	1	1	--	1	--	5	I	--	I	1	I	4	IV
P2	1	--	--	1	1	--	2	--	3	III	--	I	1	I	5	IV
P3	1	--	--	1	1	--	2	--	2	IV	--	I	1	I	5	IV
P4	--	--	--	1	1	--	2	--	1	IV	--	I	1	I	5	III

Terminal setules on spines of all exopodites; group of strong cilia on base of median seta on third endopodite segment only in second and third legs.

FIGURE 4.—*Hemicyclops adhaerens* (Williams), female: *a*, Habitus, dorsal aspect. *b*, Right maxilliped, dorsal (anterior) view. *c*, Right first swimming leg with coxal plate, ventral (anterior) view. *d*, Right second swimming leg with coxal plate, ventral (anterior) view. *e*, Right third swimming leg with coxal plate, ventral (anterior) view. *f*, Right fourth swimming leg with coxal plate, ventral (anterior) view. *g*, Right fifth leg, ventral view. *h*, Left sixth leg, dorsal view. *i*, Right caudal ramus, dorsal view. Scale B (fig. 2) applies to *a*; E to *c–f*; F to *b*, *g*, and *i*; and G to *h*.



For Explanation, See Opposite Page

Seta on proximal segment of fifth legs short; distal podomere a shape different from that of *thysanotus*, with spinules on inner and outer sides mainly in 2 patches near spines; seta on this segment subterminal, only as long as spine on its inner side.

Sixth legs consisting of 3 setae, borne on a papilla sunk between 2 flaps, near middle of genital segment.

No male has yet been reported. A spermatophore was, however, attached to the genital segment of the female depicted (fig. 4*a*); it is similar to those found in this position on *thysanotus*.

REMARKS: Williams' description and figures make it relatively easy to identify my specimen with his species in spite of some discrepancies. That of maxillipedal segmentation is probably due to a difference in interpretation; others (such as ciliation of some antennular setae and armature of third antennal, terminal maxillar, and last maxillipedal segments) may be differences in observation; but the presence of a single element on the mandible can only be explained, in my opinion, by supposing that this appendage was mutilated in his specimen. Since the mouthparts are very difficult to dissect free in poecilostome copepods, and since Williams implied in his description that he was uncertain about the exact relation of parts in this region, this assumption does not seem unreasonable.

Wilson (1932b) did not differentiate his species in any way from *adhaerens;* nor did he state what features of *americanus* he considered diagnostic. Examination of his type specimens failed to disclose any evidence for partial fusion of the genital with the first abdominal segment, an additional seta on the second antennal segment, the peculiar ornamentation of the terminal curved setae on the antenna, or the extensive spinulation and fourth spine on the fifth leg. In other respects, his descriptions and figures are close both to Williams' account and my own observations, and the name of his species is thus considered a synonym of *adhaerens*.

H. adhaerens is quite distinct from *thysanotus* as the description above indicates. Its differences from the other species discussed in this paper are considered in the accounts of those species.

DISTRIBUTION: Specimens have been found only at Wickford, Rhode Island, and in Chesapeake Bay. None occurred in the only collection made locally for it (p. 162). Correspondence with Dr. C. J. Fish and the presence of a single female in a collection made specifically for this copepod by Drs. Moore and Riser suggest that the species may no longer be abundant in the type locality, or that the proper habitat is still unknown.

Hemicyclops subadhaerens new species

FIGURES 5–7

Hemicyclops pugettensis, Gooding, 1958, p. 699 (second paragraph), not Light and Hartman, 1937.

TYPES: The holotype, an ovigerous female, USNM 101730, was obtained in "burrow water" (see p. 160), C.6, April 6, 1958; it has been dissected. The allotype male, USNM 101731, from which figures 6, *e–i*, and 7 were drawn, was found in washings from a *Callianassa californiensis* collected at the same place, February 11, 1956. Paratypes from several localities have also been deposited in the U.S. National Museum, Nos. 101371–101378.

OTHER MATERIAL EXAMINED: From "burrow water": C.6: 6 females, 11 males, 7 juveniles, February 2, 1958. 11 females, 7 males, 1 juvenile, April 6, 1958. C.7a: 1 male, February 3, 1958. C.7b: 4 females, 1 juvenile, February 3, 1958.

From washings of *Callianassa californiensis:* C.3: 2 females, 1 male from 6 of 19 hosts. C.6: 1 female, 1 juvenile from 2 of 12 hosts, February 11, 1956. 1 male from 1 of 6 hosts, February 25, 1956. 1 female from 1 of 4 hosts, March 16, 1956. 2 females from 1 of 12 hosts, February 2, 1958. C.10: 2 females from 40 hosts; figure 6*a* is based on one and figures 5 and 6*b–d* on the other. C.11: 1 female.

DESCRIPTION OF THE FEMALE: As that for *adhaerens* (p. 177), except for the following characters. Body 2.08 mm. (mean of 7 specimens, range 1.97–2.24 mm.) in length; width of prosome 0.91 mm. (0.74–1.2 mm.). Inner dorsolateral seta on caudal rami rather longer in proportion to the others. Armature and ornamentation of appendages in general more strongly developed. Denticles on labium much stronger and more widely spaced; arranged in 2 deep crescents, one on either side of midline. Mandible with a rudimentary second seta. Ventral spine on terminal segment of maxilliped with 3–5 denticles on anteroventral side. Terminal spine on fifth legs proportionately smaller; setae on both podomeres longer: specifically, seta on terminal segment longer than terminal spine. Ornamentation of distal segment stronger and more extensive. Color in life very similar to that of *thysanotus*.

DESCRIPTION OF THE MALE: Size of body, unlike condition in *thysanotus*, more or less equaling that of female: 2.05 mm. (mean of 7 specimens, range 1.9–2.3 mm.) long, width of prosome 0.8 mm. (0.77–0.84 mm.). General appearance very similar. Spermatophores attached to genital segment of female all flattened but, when in body of male, like those of *thysanotus*.

Antennule, antenna, mandible, maxillule, and maxilla essentially the same as in female, although maxilla has a peculiar hump on outer side of base of second segment which is not found in that of female.

Maxilliped, as is usual in poecilostomes, a prehensile structure, similar to that of *thysanotus*, but: first segment with a small hooklike process and 2 setae on inner face; second segment not as wide and bearing a peculiar "cock's comb" projection also on inner face; last segment with attenuated tip, ornamented with scalelike thickenings, and 2 setae (if element on inner side of angle—like that similarly placed in *thysanotus*—actually represents a seta).

Endopodites of second and, to a lesser extent, third legs very much more elongate than those of female, as are spines—particularly the innermost—on these rami; but setae on third segment somewhat reduced. Armature of all legs as represented in table for female *adhaerens* (p. 178) and ornamentation shown in figure 5*f-i*; both like those of female.

Spines on outer edge distal segment of fifth legs rather more offset; lengths of terminal spine and seta next to it not as divergent as, and ornamentation rather less than, in female.

Sixth legs covering a much smaller area of genital segment than in *thysanotus* and spine usually extending posteriorly, but general structure of appendage similar to male of that species.

Remarks: As the descriptions and figures show, this species is very close to *adhaerens* (hence its name). The differences between the females (it is unfortunate that the male *adhaerens* is unknown) seem almost of subspecific rank. However, with no intermediate morphological forms, well-separated ranges and the apparent difference in habitat, I think that their relation can at present be best indicated by making *subadhaerens* of equal rank.

Since this species apparently occupies the same range as *thysanotus* and is also associated with *Callianassa* (see below), it might represent one of the forms now equated with *thysanotus* (*callianassae* or *puget-tensis*). However, reference to the literature showed that the only evidence in favor of this view was Wilson's figure (1935, pl. 27,

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Figure 5.—*Hemicyclops subadhaerens*, new species, female: *a*, Left mandible, ventral (posterior) view. *b*, Left maxillule, dorsal (posterior) view. *c*, Left maxilla, dorsal (anterior) view. *d*, Right maxilliped, ventral (posterior) view (flattened). *e*, Detail of ventral terminal spine on the maxilliped. *f*, Left first swimming leg with coxal plate, ventral (anterior) view. *g*, Left second swimming leg with coxal plate, ventral (anterior) view. *h*, Left third swimming leg with coxal plate, ventral (anterior) view. *i*, Left fourth swimming leg with coxal plate, ventral (anterior) view. *j*, Left fifth leg, ventral view. *k*, Left sixth leg, ventrolateral view. *l*, Left caudal ramus, dorsal view. Scale D (fig. 2) applies to *f–j* and *l*; E to *c–d*; F to *a–b* and *k*; and G to *e*.

For Explanation, See Opposite Page

fig. 25) of the female *callianassae*, and a study of the type material of the latter (p. 165) has made it plain that Wilson was not dealing with *subadhaerens*.

It is necessary nonetheless to distinguish *subadhaerens* from *thysanotus*. In life, a difference is easily seen since *subadhaerens* carries the fourth legs characteristically at right angles to the ventral body surface. It is possible to distinguish even the youngest stages that I have examined in this way. Preserved adults can easily be separated by the condition of the genital segment in the females and the sixth legs in the males. It is only when dead immature specimens are being sorted that one need resort to the key characters given (p. 165).

Distribution: This species has been found from Nanaimo, British Columbia, to Bodega Bay, California. The data available suggest that both sexes are associated with *Callianassa californiensis* but occur in the burrow rather than on the body of the animal. This behavior is most clearly shown by the collection at C.6 on February 2, 1958, when 24 specimens were recovered from "burrow water"—in this case about 200 cc.—and only 2 from 12 hosts. Only the later developmental stages have been found.

Hemicyclops elongatus Wilson

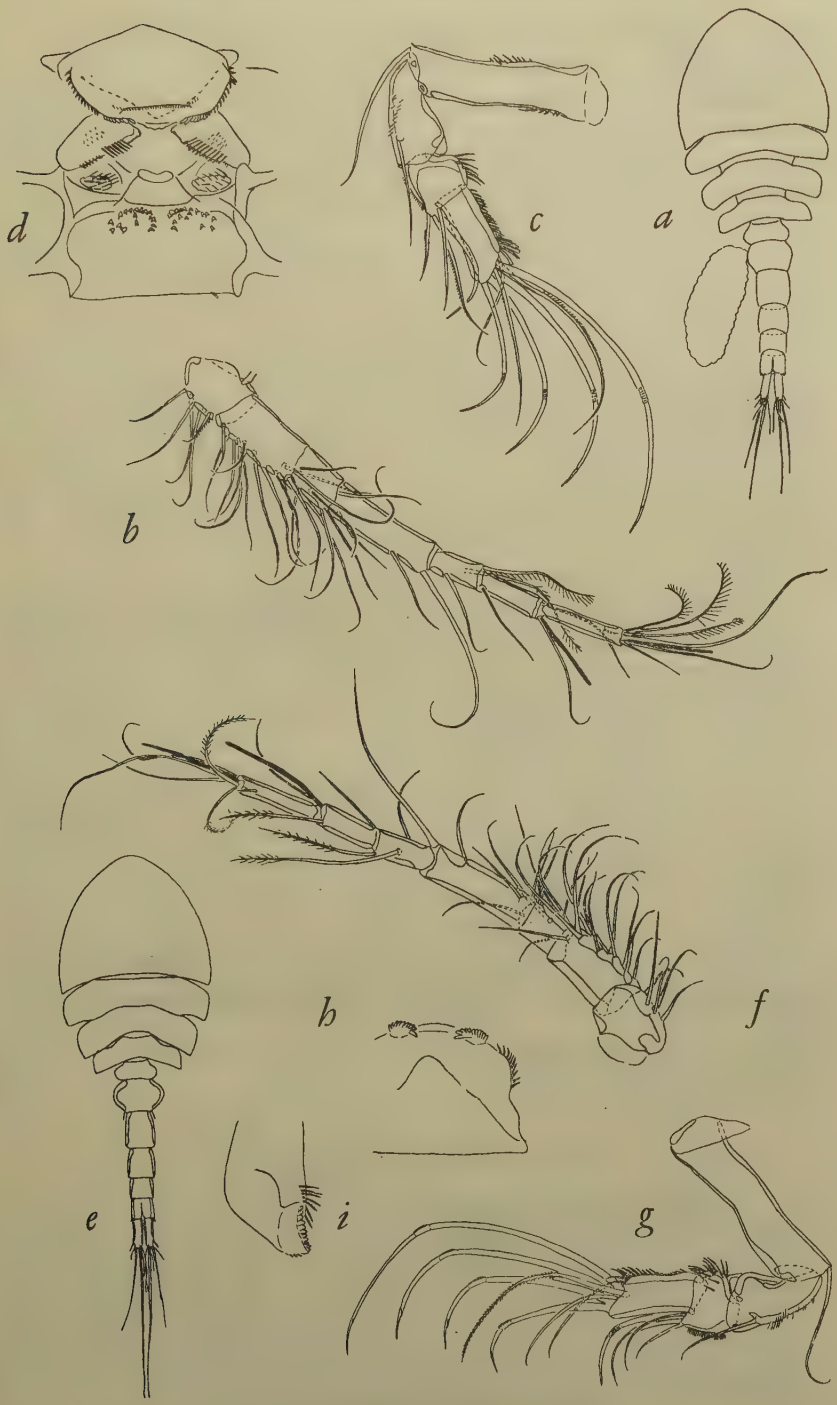
Figure 8

Hemicyclops elongatus Wilson, 1937, pp. 206–208, figs. 1–6.—Nicholls, 1944, p. 49.—Sewell, 1949, pp. 68–69.

Type and specimen examined: Holotype female, USNM 60431, from gill cavity of *Callianassa* sp., Salaverry, North Peru, F. Sears, October 21, 1926. This, the only known specimen, was examined without dissection in alcohol.

Redescription of the female: Habitus of body agreeing with Wilson's description except that terga of prosomal segments now not "closely imbricate" (compare Wilson's, 1937, fig. 1 and my fig. 8*a*) possibly due to shrinkage during prolonged immersion in alcohol. The apparent fold in the exoskeleton at the anterior end of the cephalothorax and the fact that my measurements make the body somewhat smaller (length 2.7 mm. instead of 3.0 mm., 0.89 mm. wide rather than 0.90

Figure 6.—*Hemicyclops subadhaerens*, new species: *a–d*, Female: *a*, Habitus, dorsal aspect. *b*, Right antennule, ventral (posterior) view. *c*, Left antenna, dorsal (posterior) view. *d*, Oral area (without mouthparts), ventral view. *e–i*, Male: *e*, Habitus, dorsal aspect. *f*, Left antennule, dorsal (anterior) view. *g*, Right antenna, dorsal (posterior) view. *h*, Labrum, dorsal view. *i*, Right paragnath, ventral (posterior) view. Scale A (fig. 2) applies to *a* and *e*; D to *b* and *f*; E to *c–d* and *g–h*; and G to *i*.



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mm.) may also be due to this cause. Line of small denticles following outside of each distal edge of anal segment.

Caudal rami more than 4 times as long as wide. In addition to 4 terminal setae mentioned by Wilson, a small seta borne dorsally a short way from tip on outer side and a longer one in usual position near inner corner. Rudimentary basal element on outer side was not observed.

Antennules 7-segmented but division between first and second segments indistinct. Several setae with transverse rings of thickening; ciliation not observed on any.

Details of appendages between antennules and swimming legs could not be determined. (Figure 8*d* of the maxilliped is approximate only and absence from it of features which might be expected should not be considered evidence that they do not occur.) Antenna 4-segmented; inner distal corner of its penultimate segment bearing a slender curved seta and other setalike elements; the terminal with curved and normal setae. The appendage may thus be presumed to resemble that of *adhaerens* or *subadhaerens*.

Swimming legs as in figure 8*e–h*; armature and basic ornamentation same as that given for *adhaerens* (p. 178) except for possible lack of a seta on outer side basipodite of fourth legs. (Wilson's "fourth leg," 1937, fig. 5, is clearly a reversed view of the first and thus bears little resemblance to the actual appendage.) "Spines" on outer distal corners of first and second endopod segments not true spines, as Wilson's description and figures would imply, but unarticulated projections of these podomeres. Only 2 of the "row of four short spines around the tip" of third endopod segment in first leg discernible and these—here termed spinules—occur similarly on second leg.

Contrary to Wilson's statement (1937, p. 208) and his figure 6, a seta occurs on proximal segment of fifth legs. Spinules on distal podomere not extending further along outer margin than base of first spine.

Sixth legs represented by 3 setae (not 2) near oviducal openings; appendage apparently like that of *adhaerens*.

FIGURE 7.—*Hemicyclops subadhaerens*, new species, male: *a*, Tip of left mandible, ventral (posterior) view (flattened). *b*, Right maxillule, dorsal (posterior) view. *c*, Left maxilla, ventral (posterior) view. *d*, Right maxilliped, ventral (posterior) view. *e*, Left first swimming leg with coxal plate, ventral (anterior) view. *f*, Left second swimming leg with coxal plate, ventral (anterior) view. *g*, Left third swimming leg with coxal plate, ventral (anterior) view. *h*, Left fourth swimming leg with coxal plate, ventral (anterior) view. *i*, Left fifth leg, dorsal view. *j*, Right sixth leg, ventral view. *k*, Left caudal ramus, dorsal view. Scale D (fig. 2) applies to *d–h*; E to *c* and *i–k*; and F to *a–b*.

For Explanation, See Opposite Page

The male is unknown.

REMARKS: This species cannot with absolute certainty be placed in the genus *Hemicyclops* without further knowledge of its mouthparts, but there is good evidence for and apparently none against placing it here. There is also no assurance that the holotype is mature.

H. elongatus is very similar to *adhaerens* and *subadhaerens* in general characters of body and the appendages known. The only important differences appear to be its size, greater length:width ratio of the caudal rami and last antennular segment, and the segmentation of the latter appendage.

DISTRIBUTION: The only information is that given above. Again, there is insufficient evidence to place the species definitely as an associate of *Callianassa*, although Wilson's statement that the holotype occurred in the gill-chamber is more positive than our present knowledge about *subadhaerens*. But it is possible that *elongatus* also occurs in burrow water.

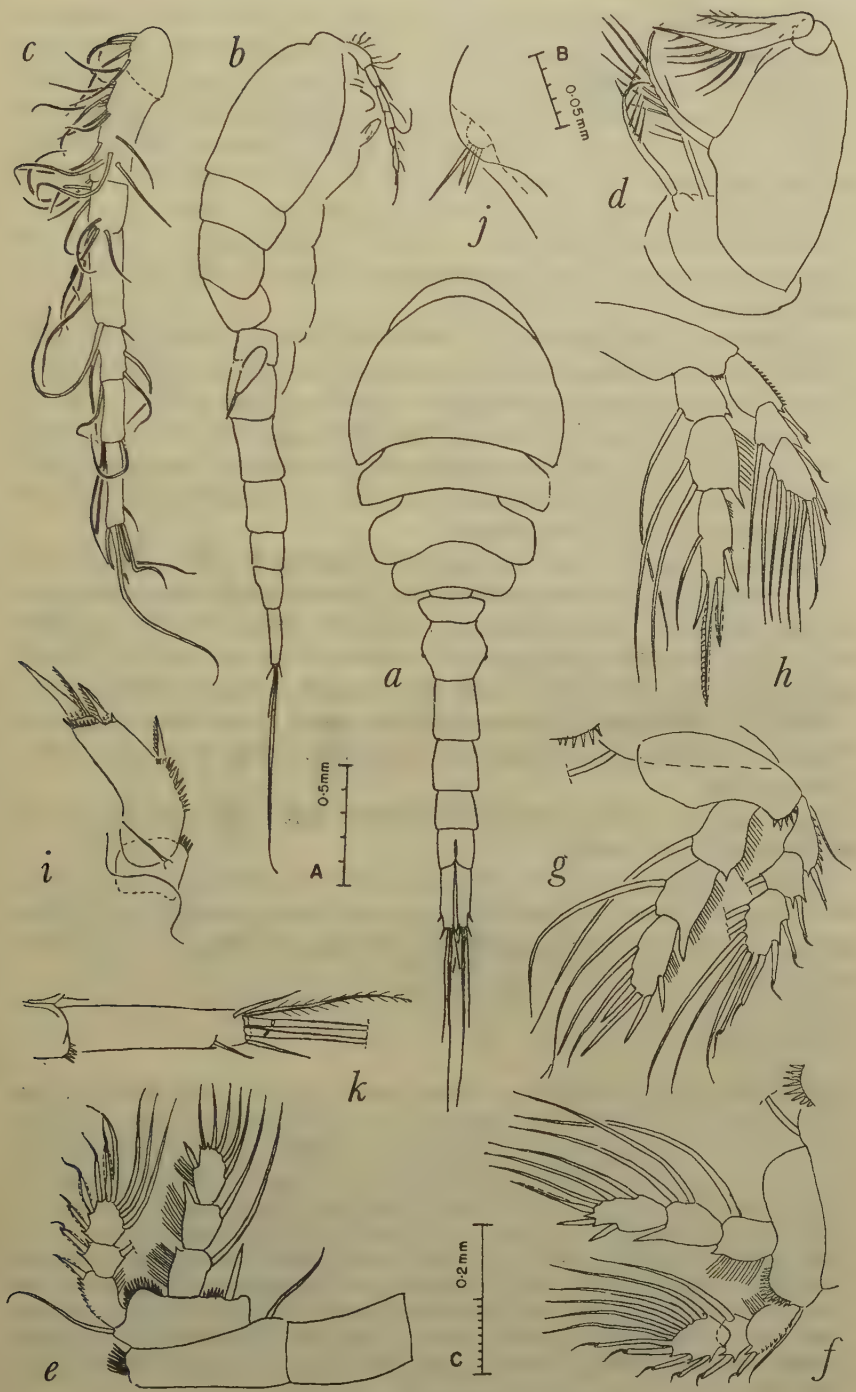
Hemicyclops arenicolae, new species

FIGURES 9–10

SPECIMENS EXAMINED: Wellfleet Harbor, Cape Cod, Massachusetts, 26 females, 27 males, and 13 juveniles from burrows and body surface of 4 *Arenicola cristata* Stimpson, sand and rubble beach, G. M. Moore and M. Pettibone, July 3, 1954; 2 females and 2 males were dissected; figures 9*a–c* and *f–p* and 10 are based on one of each sex. Lackey's Bay, Woods Hole, Massachusetts, 3 females, 4 males, and 1 juvenile from the same host, Moore and Pettibone, July 31, 1954; 1 female and 1 male of this lot were dissected; figure 9*d–e* is from this female.

TYPES: The holotype, USNM 101732, a dissected female, and the allotype male, USNM 101733, are both from the Wellfleet sample. Paratypes from Wellfleet, 21 females and 21 males, and, from Lackey's Bay, 2 females and 3 males, have also been deposited in the U.S. National Museum, Nos. 101370 and 101369 respectively.

FIGURE 8.—*Hemicyclops elongatus* Wilson, female: *a*, Habitus, dorsal aspect. *b*, Habitus, lateral aspect. *c*, Right antennule, ventral (posterior) view. *d*, Left maxilliped, ventral (posterior) view. *e*, Left first swimming leg with coxal plate, ventral (anterior) view. *f*, Left second swimming leg with part of coxal plate, ventral (anterior) view. *g*, Left third swimming leg with part of coxal plate, ventral (anterior) view. *h*, Left fourth swimming leg, ventral (anterior) view. *i*, Left fifth leg, dorsal view. *j*, Left sixth leg, dorsal view. *k*, Left caudal ramus, dorsal view. All appendages were drawn in situ. Scale A applies to *a* and *b*; B to *d* and *j*; and C to the remainder.



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Description of the female: Body 2.65 mm. in length (mean of 6 specimens, range 2.54–3.0 mm.). Prosome narrower (0.89 mm., 0.84–0.94 mm.) in proportion to its length than in any of the other species; terga separated, their corners rounded. Urosome more than twice length of prosome. Ovisacs long and narrow. First 3 abdominal segments with narrow ventral membrane posteriorly; anal segment with row of small spinules along posterior border.

Length of caudal rami about 3 times width; hairlike element on outer side near base less well-developed than in *H. adhaerens* or *subadhaerens*.

Antennule as in figure 9*b*. Curved seta on outer side of slightly protruding distal corner on third segment of antenna rather stouter than in the other species; spines on tip of projection like those of *thysanotus*. Inner faces of second and third segments swollen; with large patches of regularly arranged spinules; rows of larger spinules (which have a peculiar flattened and frayed appearance) on outer sides third and terminal segments.

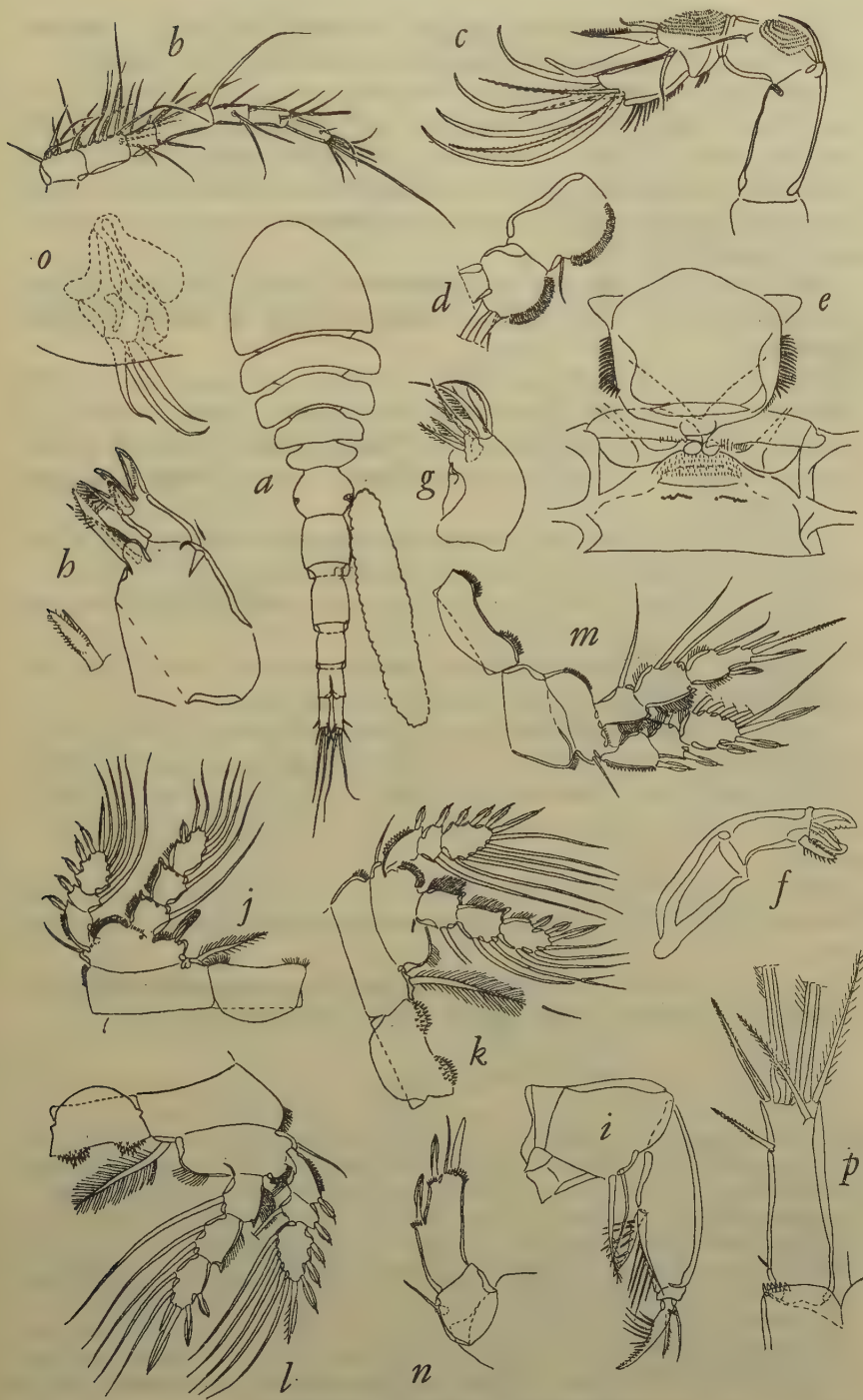
Spinules on labrum confined to a row along each edge. Paragnath with cutting edge notched; row of long cilia on posterior surface not as well developed as in *adhaerens*. Labium with very fine spinules confined to raised median portion which abuts on roof of mouth cavity; occasionally a row of small denticles on each side behind these.

Mandible may have no trace of a second seta in addition to curved element and blade. Latter somewhat curved, unlike condition in the other species.

Maxillule much like that of *adhaerens* but with well-developed anterodorsal prominence.

Terminal armature of maxilla similar to condition in *adhaerens;* setule-bearing seta on first segment even more enlarged. On one maxilla of holotype, armature on this segment is that shown on inset to figure 9*h*.

Figure 9.—*Hemicyclops arenicolae*, new species, female: *a*, Habitus, dorsal aspect. *b*, Left antennule, ventral (posterior) view. *c*, Left antenna, dorsal (posterior) view. *d*, Second and third antennal segments, lateral (outer) view. *e*, Mouth area (without appendages), ventral view. *f*, Right mandible, ventral (posterior) view. *g*, Left maxillule, dorsomedial (posteromedial) view. *h*, Left maxilla, ventral (posterior) view, with detail of unusual element on basal segment of right maxilla. *i*, Left maxilliped, dorsal (anterior) view. *j*, Left first swimming leg with coxal plate, ventral (anterior) view. *k*, Left second swimming leg with coxal plate, ventral (anterior) view. *l*, Left third swimming leg with coxal plate, ventral (anterior) view. *m*, Right fourth swimming leg with coxal plate, ventral (anterior) view. *n*, Left fifth leg, ventral view. *o*, Left sixth leg, dorsal view. *p*, Right caudal ramus, dorsal view. Scale A (fig. 2) applies to *a*; C to *b* and *j–n*; E to *c–i* and *p*; and G to *o*.



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Ventral spine on terminal segment of maxilliped rather reduced; large process stout and, as in the other species, strongly ciliated.

Swimming legs like those of *adhaerens;* armature represented by same formula (p. 178) and ornamentation similar except that spinules on coxal plates of second and third legs form patches rather than being confined to edge, setules on exopod spines shorter and strong ciliation at base of median seta on third endopod segment apparently absent on all legs.

Fifth and sixth legs also very similar to those of *adhaerens* but former lacking spinules on basal segment and on edges of distal podomere.

Description of the male: Body longer (2.83 mm., mean of 10 specimens, range 2.67–3.24 mm.) than that of female; width of prosome 0.9 mm. (0.84–0.94 mm.). Genital segment almost square in dorsal view. No spermatophores found. Caudal rami like those of female.

Antennule similar to, but patches of spinules on second and third segments of antenna more extensive than in female.

Mandible occasionally with a small setule in addition to the normal seta. Maxillule and maxilla as in female.

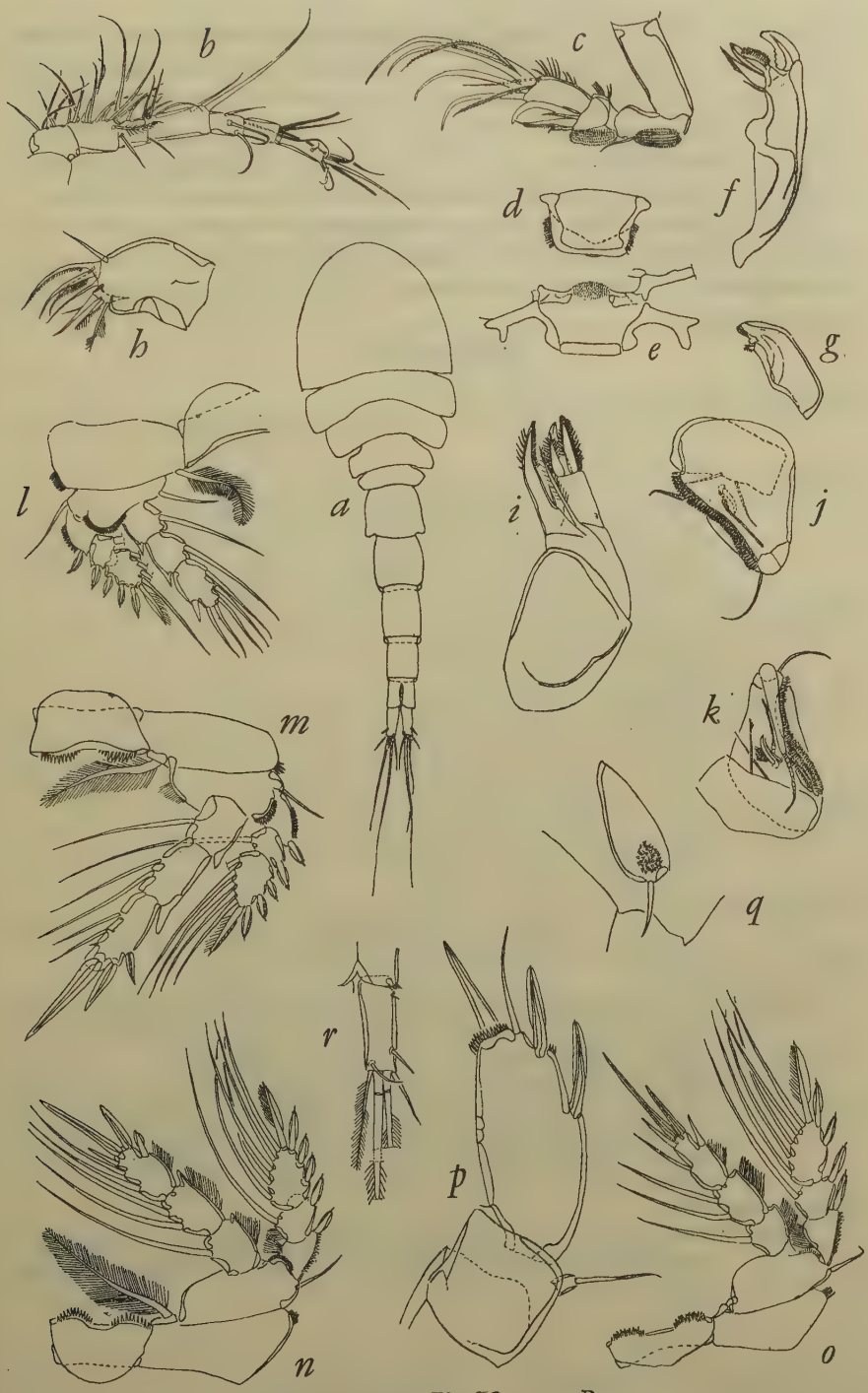
Maxilliped similar to that of male *subadhaerens* but with 1 long seta on last segment and lacking "cock's comb" on second.

Swimming legs larger than those of female; spines longer and better developed, but armature the same. Endopodites of second and third legs, like condition in male *subadhaerens*, longer than those of female but here last seta on third podomere of second leg reduced to a minute setule.

Fifth leg with basal podomere partly fused to thoracic segment. Ornamentation reduced to a ventral line of spinules at base of terminal spine.

Sixth legs like those of *subadhaerens* male but completely hidden in dorsal view; patches of fine denticles on their ventral surface.

Figure 10.—*Hemicyclops arenicolae*, new species, male: *a*, Habitus, dorsal aspect. *b*, Right antennule, dorsal (anterior) view. *c*, Right antenna, dorsal (posterior) view. *d*, Labrum, ventral view. *e*, Labium, ventral view. *f*, Left mandible, ventral (posterior) view. *g*, Left paragnath, ventral (posterior) view. *h*, Right maxillule, ventral (anterior) view. *i*, Right maxilla, anterodorsal view. *j*, Right maxilliped, ventrolateral view. *k*, Left maxilliped from inner side. *l*, Right first swimming leg with coxal plate, ventral (anterior) view. *m*, Left second swimming leg with coxal plate, ventral (anterior) view. *n*, Right third swimming leg with coxal plate, ventral (anterior) view. *o*, Right fourth swimming leg with coxal plate, ventral (anterior) view. *p*, Right fifth leg, ventral view. *q*, Left sixth leg, ventral view. *r*, Right caudal ramus, dorsal view. Scale A (fig. 2) applies to *a*; C to *b*, *d–e*, *j–o*, and *r*; D to *c*; and E to *f–i* and *p–q*.



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REMARKS: The species may be distinguished from *adhaerens* and *subadhaerens* mainly by its length, the proportions of body and caudal rami, greater development of the curved seta on third antennal segment and ornamentation of that appendage, armature of maxilliped, and ornamentation of fifth legs and from *H. elongatus* by the third to seventh of these characters. It is not particularly close to any other form.

DISTRIBUTION: All that is known at present is that both sexes are external associates of *Arenicola cristata* from either side of Cape Cod, Massachusetts. Only the later copepod stages are represented in the two collections.

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